

PROGRESS OF THE MICROBIOLOGICAL
LAKESHORE CAPACITY STUDY IN 1977

December 1977



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INTERIM REPORT - 1

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PROGRESS OF THE MICROBIOLOGICAL LAKESHORE CAPACITY
STUDY IN 1977

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Part 1

Report on Field Work

Microbiology Component: Report on Field Work
Conducted in 1977.

The Microbiology Component of the Lakeshore Capacity Study began its field work by carrying out lake sampling in the Muskoka Region during the summer and fall of 1976. With the hiring of full-time staff and summer students more extensive studies were initiated in the spring of this year.

During the spring and early part of this summer two small mobile laboratories located at the Ministry of Transportation and Communications yard in Huntsville served as the headquarters for a field staff of 10. At that temporary laboratory site working space and storage facilities were extremely limited which made for poor working conditions and for great difficulty in the training of new staff. However, the sampling surveys were conducted as scheduled with the lakes being examined for various bacterial parameters such as Pseudomonas aeruginosa, fecal coliforms, total coliforms and heterotrophic bacteria. In addition chemical parameters such as chlorophyll a,b, and various forms of carbon, nitrogen and phosphorus were also determined in water samples.

From each lake water samples were collected from mid-lake sampling stations and analysed for chemical parameters by the Water Quality staff in Dorset and in Toronto. Sediment and surface water samples were obtained from each lake during the summer from shoreline stations that reflected the degree and type of development of the lakeshore. At each station temperature and dissolved oxygen reading were recorded. At the completion of field sampling samples were returned to the mobile laboratories for analyses by membrane filtration, most probable number and spread plate procedures.

During the winter and throughout the spring of this year much time was devoted to the establishment of new laboratory facilities. A 50 ft. mobile laboratory was purchased and furnished with equipment that is essential to the operation of a microbiology laboratory. The new laboratory houses an office, spacious incubators, a water purification system and equipment required for preparation and sterilization of bacterial growth media. Recent equipment acquisitions provide the laboratory with the capability of conducting sero-typing and phage-typing of bacterial isolates. Located at a site near Dorset the new mobile laboratory together with the smaller units, provide the field staff with ample space and greatly improved working conditions.

A new type of study was undertaken by the Microbiology Component this year with the initiation of an epidemiology study of Pseudomonas aeruginosa related ear infections. This study was carried out during the summer months and involved Gravenhurst physicians, Muskoka Bay cottagers and children in the swimming classes at Gull Lake Park.

The Epidemiology Project involved surveying of participants for information regarding their past and present swimming habits and history of ear infections. Swabs from the ear of participants were obtained on several occasions during the summer and analysed for the presence of Pseudomonas aeruginosa. Intensive sampling of the shoreline water and sediment of Muskoka Bay and Gull Lake beach was carried out along with ear swabbing to determine the distribution of Pseudomonas aeruginosa in peoples' ears and in lakeshore water and sediments.

Serotyping and phage typing of the Pseudomonas aeruginosa cultures obtained during this study is continuing at the Dorset laboratory. The Epidemiology Project was well received by the cottagers and swimmers with most participants showing true appreciation that such a study was being conducted.

Part - 2

Background To The Lakeshore Capacity Study

BACKGROUND TO THE LAKESHORE CAPACITY STUDY

The purpose of this presentation is to provide background information, definitions and theoretical concepts which are needed in the discussion of the role that the study of microbiology can play in the final statement(s) from the Lakeshore Capacity Study. Much of this information is taken for granted by microbiologists but in the context of a multi-disciplinary study, such as the Lakeshore Capacity Study, this information needs to be stated in terms which are understandable by all.

Although microbiologists aspire to become environmental ecologists and to make statements about the effect of environmental changes on the microbial population, the main purpose of the study of microbiology to studies such as this has to be the statement of the public health significance of any environmental or man-made change. This statement cannot be made by any other discipline, unless by some engineering feat all discharges and their effects are curtailed and even then the assumptions made in the engineering design must be stated in microbial terms.

In the Lakeshore Capacity Study, the public health significance statement will be in the form of a relationship between the use of water for recreational or drinking water purposes and the risk of disease within the human user. The statement will also include a listing of the sources of the risk and the nature of the risk.

The diseases, in the statement, will occur when a pathogen or disease-causing microorganism is ingested, whether accidentally or on purpose, gains entry into a wound or cut, or invades any of the mucous membranes of the human body. To these pathogens the aquatic environment is harsh and abnormal; therefore, given

time and circumstance their numbers would decrease because of death. Therefore, in the environment the distribution of pathogens tends to be limited by distance and time from the original source. This means, in practical terms, that any public health significance statement is both location or site specific and time specific. For example, a discharge near one end of a long beach may cause a problem at that end of the beach but not at the other end. Also if the discharge is stopped, given time, the problem would disappear.

So far I have been referring to the study of microbiology in general. However, microbiology can be divided into at least, four major areas of study, bacteriology, mycology (fungi), virology, and a miscellaneous category. In the Lakeshore Capacity Study, we are largely only going to be dealing with bacteria but we are aware of the others.

Earlier, I indicated that microbiology is concerned with disease and pathogens. The bacteria which fall into this category and which may be of concern to the Lakeshore Capacity Study are Salmonella, Vibrio, Yersinia, and Pseudomonas. The Salmonellae, including the bacterium, Salmonella typhi, are the causative agent for a wide range of gastro-intestinal upsets such as diarrhea, and typhoid fever. A Salmonella infection is almost always due to the ingestion of contaminated materials such as food and water. The Salmonella contamination is usually from fecal matter, or water and food which has come in contact with fecal matter.

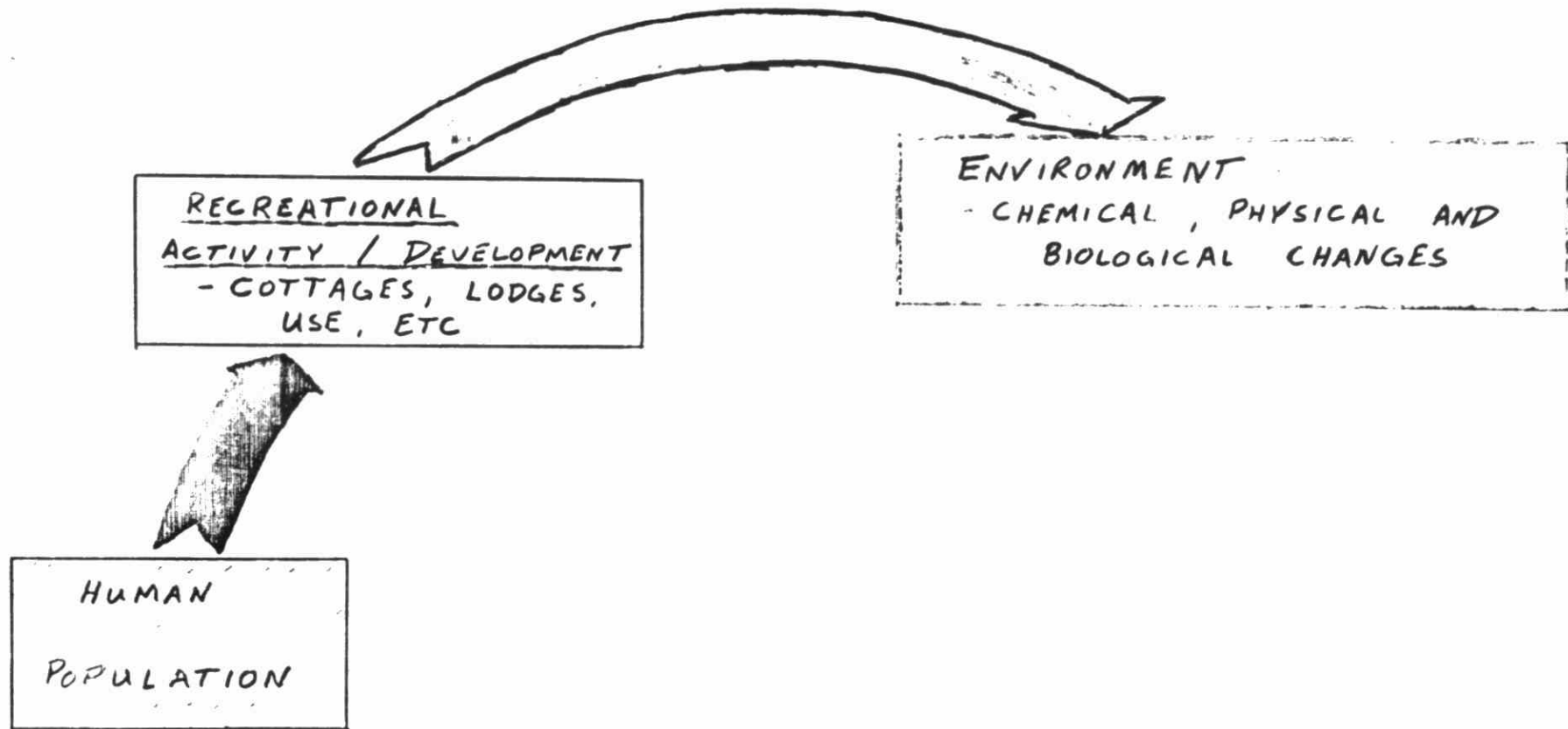
Similarly, the Vibrios, especially Vibrio cholera, are the causative agent of gastro-intestinal upsets such as diarrhea, enteritis, and cholera. The Vibrios are more of a problem in

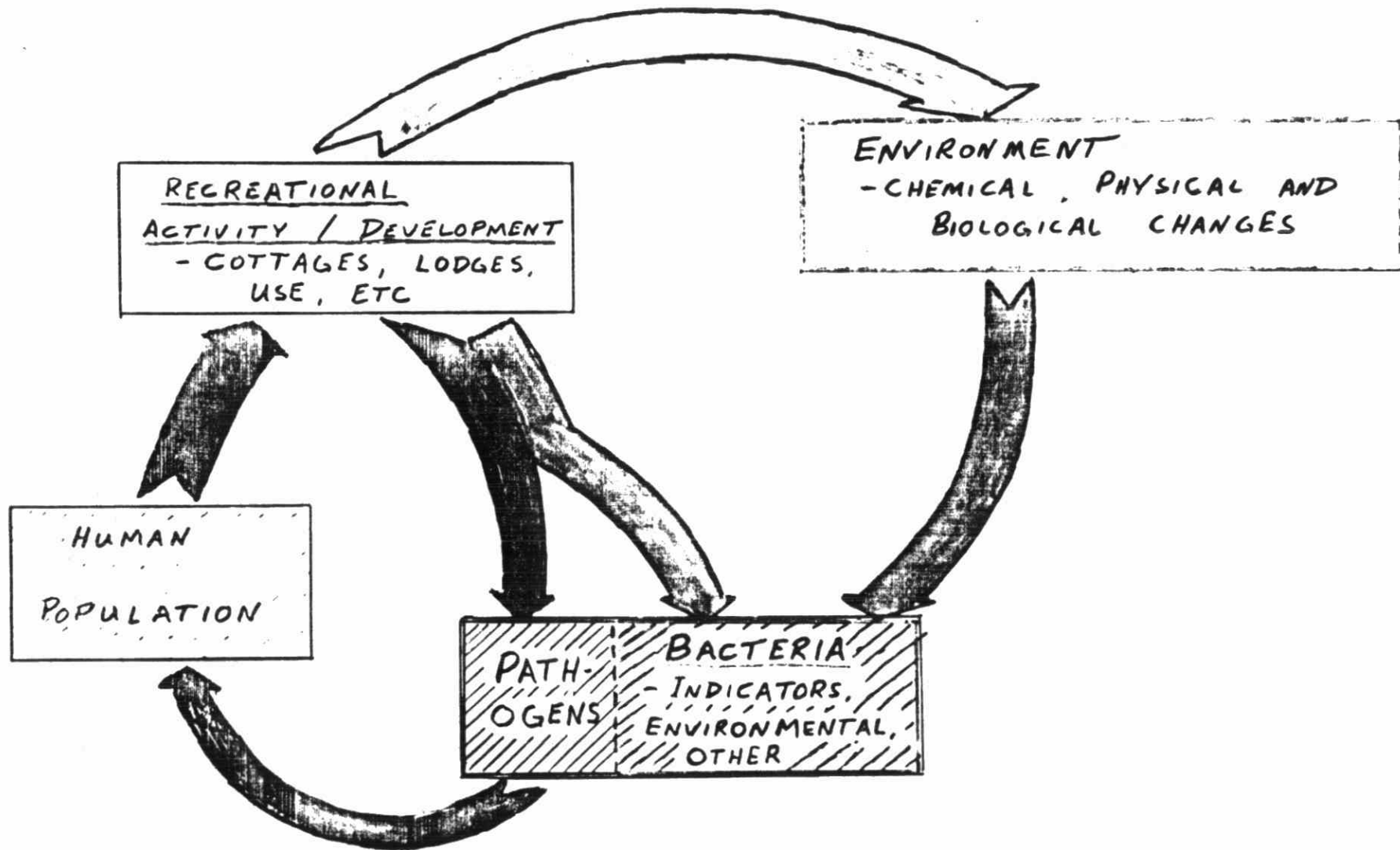
estuarine or saline waters but could occur in fresh water. Again the pathogen is contained in fecal matter and contamination of the water occurs from that source.

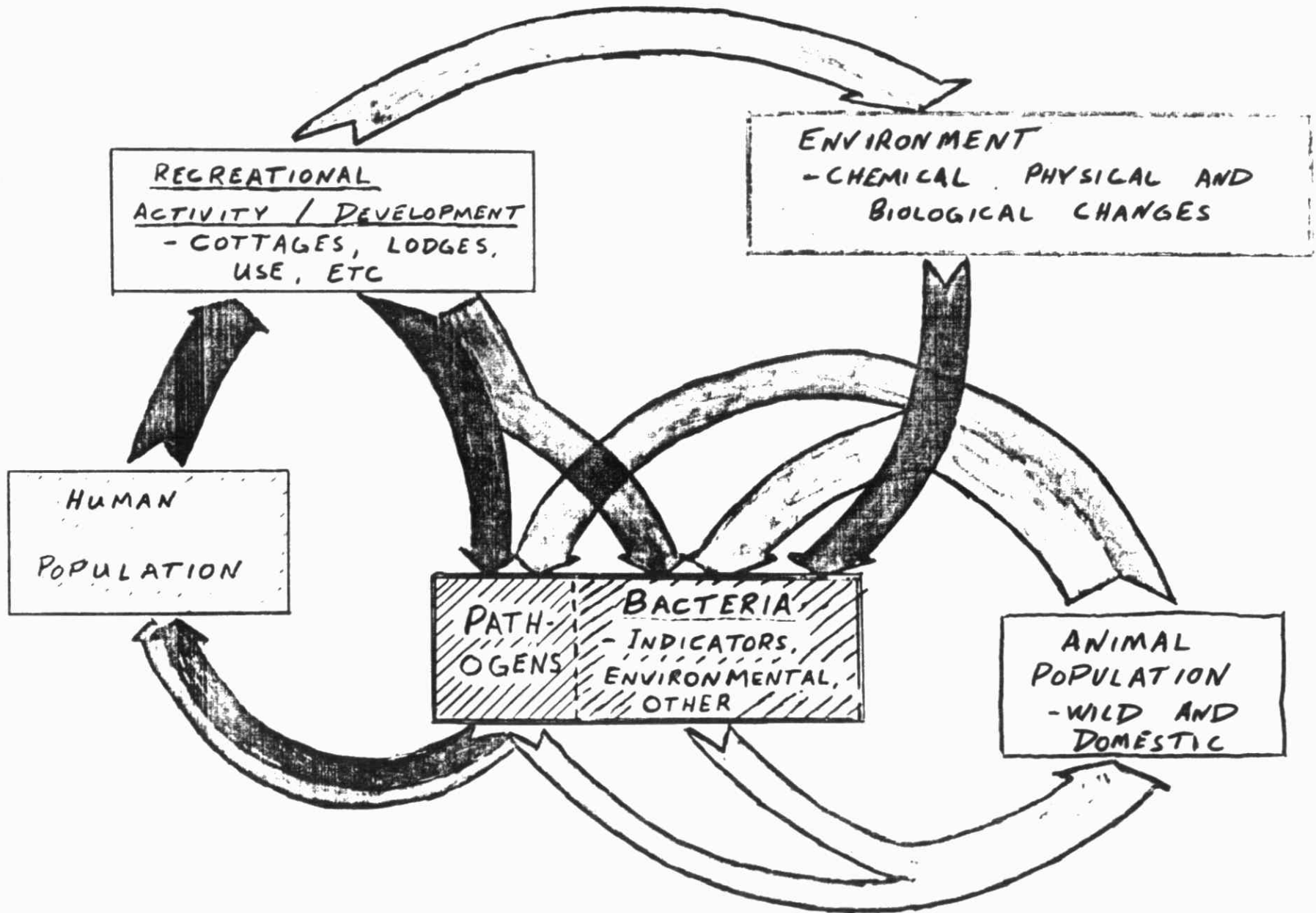
Yersinia enterocolitica is a pathogen which only recently has been recognized as a potential problem. A number of outbreaks of enteritis and abdominal pain have been reportedly caused by this organism. It has been isolated from drinking water, well water, food and a number of animal species. Very little is known about it except that in 1966 only 23 cases were reported in the world but in 1974 more than 4000 cases were reported.

Pseudomonas aeruginosa has been reported as the causative agent for a diverse group of diseases including skin and wound infections, respiratory infections, a dysenterylike enteric infection and otitis externa, an outer ear infection. This organism can be found in the stool specimens of about 10% of normally healthy persons, and in one study was isolated from about 90% of the sewage samples examined.

In the Lakeshore Capacity Study we are aware of the Salmonella and Vibrios but there is a substantial amount of information which suggests that they are not an eminent problem. A small study has been started to investigate Yersinia because of lack of information and knowledge. The major of our efforts are being expended in the study of Pseudomonas aeruginosa and otitis externa, colloquially known as 'swimmers ear'. I will be discussing this in more detail later.





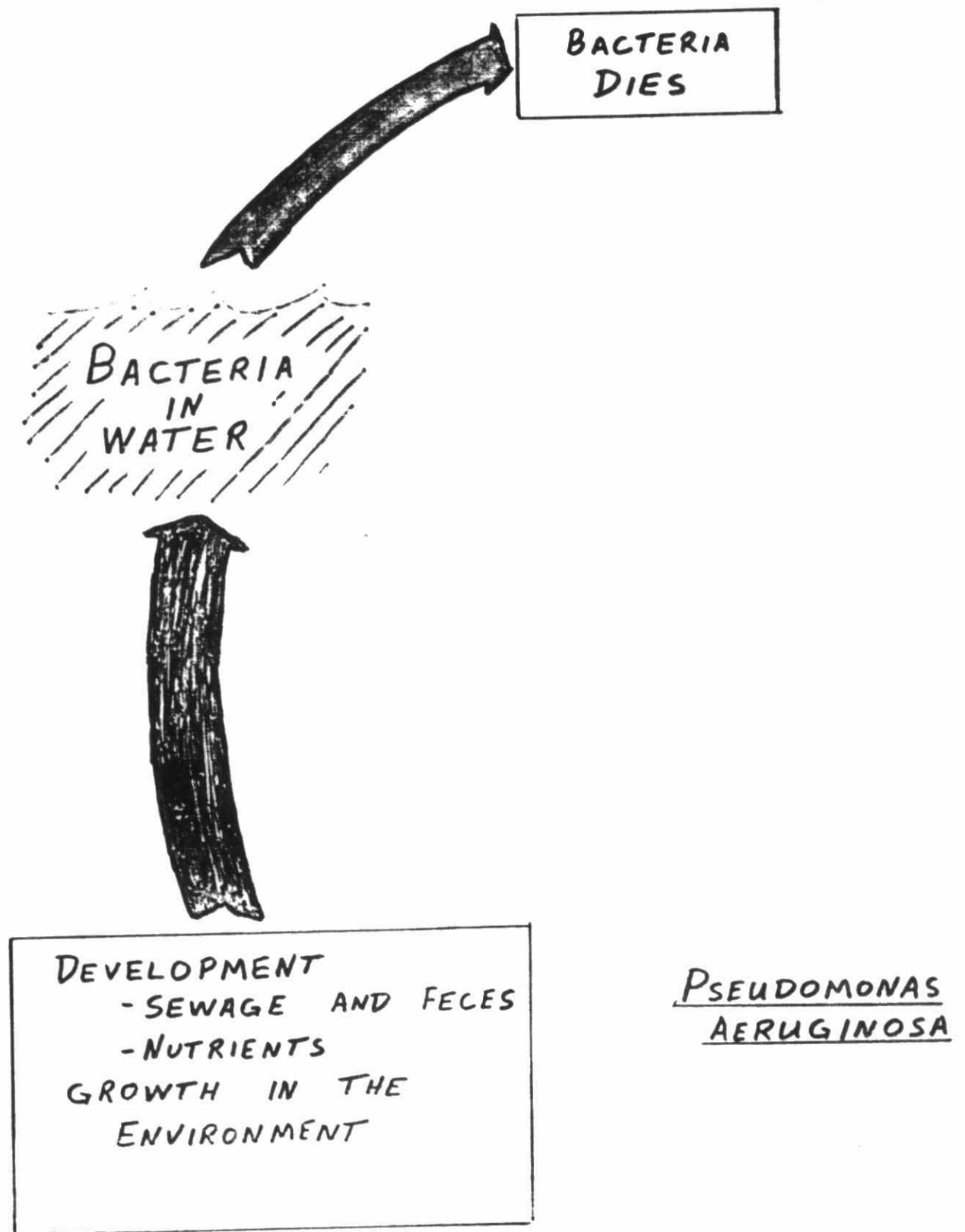


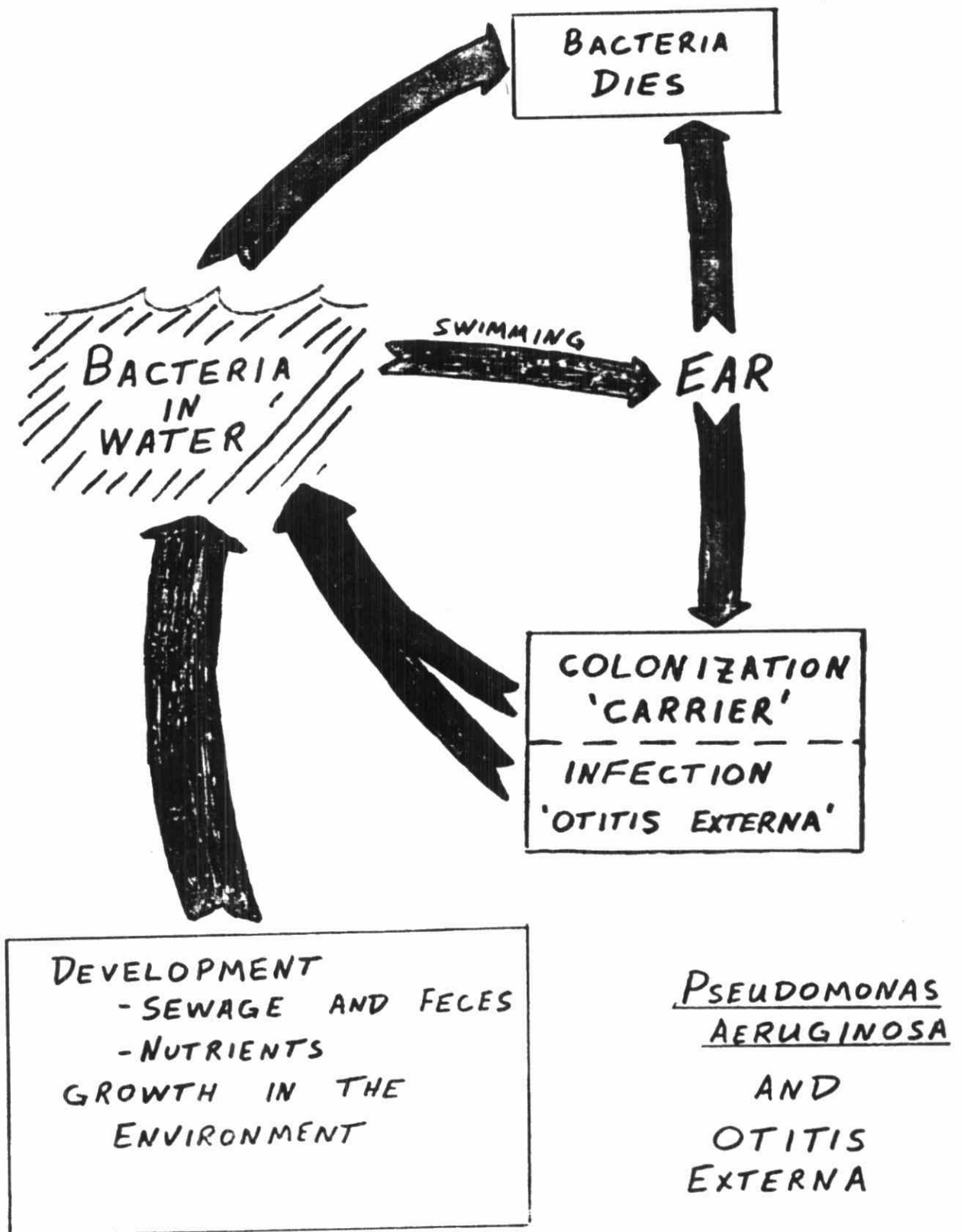
In addition to the pathogens, there are two other classes of bacteria, the indicators of fecal pollution and environmental bacteria which have been included in aspects of the Lakeshore Capacity Study. Because the major source of pathogen is fecal matter or sewage and because the pathogens are low in number and the analysis for them long and costly. Other bacteria which are found in large numbers in the fecal source have been used as indicators of the presence of feces and therefore indicators of the possible presence of pathogens. The total coliform, fecal coliform, fecal streptococcus and Pseudomonas groups of bacteria have been used as fecal pollution indicators. Note that Pseudomonas aeruginosa can be placed in both the lists of pathogens and the indicators of fecal pollution.

The environmental bacteria being examined in the Lakeshore Capacity Study, are bacteria which, in the past, have been shown to respond to the increased nutrients and chemicals or the environmental changes which accompany development of a lake, or a change in trophic status. The bacteria in this category are the heterotrophic bacteria, Aeromonas and Acinetobacter.

Effects of Recreational Activity/Development

When a human population develops an area for recreational use, it is generally agreed that the environment changes and that these changes can be measured in chemical, physical or biological terms. The study of microbiology adds to this picture yet another dimension. The recreational activity/development contributes pathogens and other bacteria directly to the environment via sewage and other means. But now the pathogens can be recycled back into the human population as diseases contracted through use of the environment. In addition pathogens and bacteria respond to the chemical and





physical changes that are occurring.

To further complicate the picture, the wild animals and domestic animal which accompany the human population contribute bacteria and may contract diseases encountered in the environment. There is also a small portion of the pathogens from animals which may cross the species boundary and be transmitted to the human population.

Pseudomonas aeruginosa and otitis externa

Let us now examine the cycle in more detail for the bacteria Pseudomonas aeruginosa and the disease, otitis externa.

Otitis externa is an infection of the outer or external ear which includes the ear canal up to the ear drum. It can be a painful infection, especially when the causative agent is Pseudomonas aeruginosa. It usually requires a doctors attention and antibiotic treatment.

In one study, 65 to 81 percent of cases of acute otitis externa were caused by the bacteria, Pseudomonas aeruginosa. This organism tends to be resistant to most antibiotics but can be adequately treated, if properly diagnosed. This bacteria is usually introduced into the water with the sewage and fecal matter associated with development. However, once it has been introduced, given the proper environmental conditions and nutrients, it can grow in the environment, but normally after a variable survival period, would die. Pseudomonas aeruginosa has not been found in any significant quantities in the animal population.

Now, when a person goes for a swim, water containing the bacteria enters the ear canal. Once in the ear, a number of courses can be followed: 1) the organism could die and cause no serious threat; 2) the bacterium could continue to inhabit the healthy ear and develop a colonized or carrier state; or 3) the ear may be stressed by the presence of the water or some other reason and the bacteria invades the tissue causing the infection. The carrier state can also be converted to the infection at a later date if the ear tissue becomes stressed. If a person in the carrier or infection state goes swimming again, some bacteria are washed from his ears; thus recontaminating the water and providing a secondary source of the bacteria.

Earlier it was stated that given the proper environmental conditions and nutrients, Pseudomonas aeruginosa could grow in the environment. The nutrients can be derived from a number of sources but one source is already being measured in the form of trophic status. The sewage which introduced the bacteria is another source.

One important environmental conditions is temperature. The response of a bacteria to changes in temperature is not a straight line function, but rather at low temperatures, there is no response to changes in temperature. When a critical temperature is reached, the response becomes very rapid and ultimately reaches a plateau. A similar but inverse response on the other side of the plateau at the higher temperatures. For Pseudomonas aeruginosa the critical temperature appears to be in the range 25 to 30°C.

Therefore, in order to examine the Pseudomonas aeruginosa - otitis externa cycle we must consider the environmental conditions, the potential sources of both nutrients and bacteria and lastly the numbers of bacteria required before the risk of infection becomes significant.

In conclusion, the purpose of the microbiology component is to examine the public health significance of the effects of recreational activity/development and to pave the way for making a statement about the public health significance.

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Part - 3

Interpretation of The 1977 Bacteriology Results

Summary

The distribution of Pseudomonas aeruginosa in eight lakes in the District of Muskoka was investigated in 1977. Densities of P. aeruginosa in water and sediment were low on the average (about 1 per 100 ml), but densities as high as 100-300 per 100 ml were occasionally observed. This bacterium was isolated more frequently and in higher numbers from samples taken along the developed portion of lakeshore. It was not isolated from the undeveloped lake (Jerry Lake). The highest number of P. aeruginosa were found at an intensively used public beach. Higher than average numbers were also occasionally observed in nutrient enriched lakes. The presence of P. aeruginosa in lakewater was associated with lakeshore development and numbers of the bacterium were dependent on lake trophic status, water temperature, and human use of the lake. A measure of human use of the lake was suggested to be number of swimmers times days of swimming per 100 ft. of lakeshore.

High densities of fecal coliforms and fecal streptococcus were also associated with the developed portion of lakeshore.

The organization of the field work, some theoretical concepts of the study, and the direction of future studies are discussed.

Introduction

Specific practical questions need to be asked about the environment for the Lakeshore Capacity Project.

1. Can the specific environmental factors that affect bacterial numbers in lakewater be identified?
2. Can these environmental characteristics be reliably measured?
3. Can the collected data be put together in a model to predict the effect of Lakeshore development on bacteriological water quality so that it can be used as a predictive tool for the management of freshwater lakes?

The Lakeshore Capacity Study Objectives

There is only one objective, and that is the production of a formula to predict the effect of lakeshore development on bacteriological water quality. The integration of the project will not necessarily make use of a mixing of the data from different components. The microbiology section has displayed an interest in establishing relationships with lake trophic status. This relationship is not of secondary interest rather it is intended to be an integral part of the predictive formula for microbiological water quality. There is very little in the microbiology study that is of secondary interest.

Definition of Lakeshore Development

The definition of Lakeshore Development would follow logically from a relationship between bacteriological water quality and the degree of shoreline development. Such a relationship was not available at the commencement of the program and only now is beginning to evolve. Several definitions of development are possible depending on the type of development - bacterial relationship obtained from actual data. In order to keep all options open the initial approach was to describe development by a variety of measurements and to test the suitability of each measurement in a multiple regression equation. The land use component was requested to collect the following data.

- a) The amount of cleared land
- b) Road length - type
- c) Bridges culverts etc - numbers
- d) Type of ground cover
- e) Type of soil
- f) Depth of soil
- g) Type of sewage disposal - septic tank
- holding tank
- aquarobic type
- age of the system
- h) Lot level - if flooded etc
- i) Size of cottage
Number of people X days of use
Number of swimmers X days of water contact

The new measure of development concentrates on the use of lakeshore by swimmers. It will likely be expressed in the following way:-

Number of swimmers per 100 ft. of lakeshore

or

Number of swimmers X days of water contact per
100 ft. of Lakeshore

Work Approach Outline

The Lakeshore Capacity Project is broken down into a number of smaller more easily managed projects. The projects initiated in 1976 and 1977 are listed in Tables 1 and 2 respectively. A flow-chart showing the relationship between some of the projects and their completion date in the multi-year plan is shown in Figure 1. Individual project reports will be made on a yearly basis whenever possible.

TABLE - 1

Recreational Lakes and Lakeshore Capacity - Projects Initiated in 1976

PROJECT TITLE	Research Inventory No.		1976	INTERIM REPORTS			FINAL
				1977	1978	1979	
The identification of coliform Bacteria isolated from Recreational Lakes in Southern Ontario	500-R00	GH - 7601	✓				
Report on the cottage survey for Waterborne diseases in Recreational Lakes	500-R00	GH - 7602					
The relationship between bacterial parameters of water quality and lakeshore development, trophic status, and other lake characteristics	510-R01	GH - 7603	✓✓	✓			
Occurrence of pathogenic bacteria in Recreational Lakes	511-R08	GH - 7604 KP	✓				
Determination of Heterotrophic Bacteria in Recreational Lakes	511-R05	GH - 7605 KP					
Pattern of Bacterial Distribution in Recreational Lakes - I. Distance From Shore	500-R03	GH - 7606					
A Comparison of Water Quality in Harp and Jerry Lakes, Adjacent Cottaged and Uncottaged Lakes on Southern Ontario's Precambrian Shield	500-R04	GH - 7607					

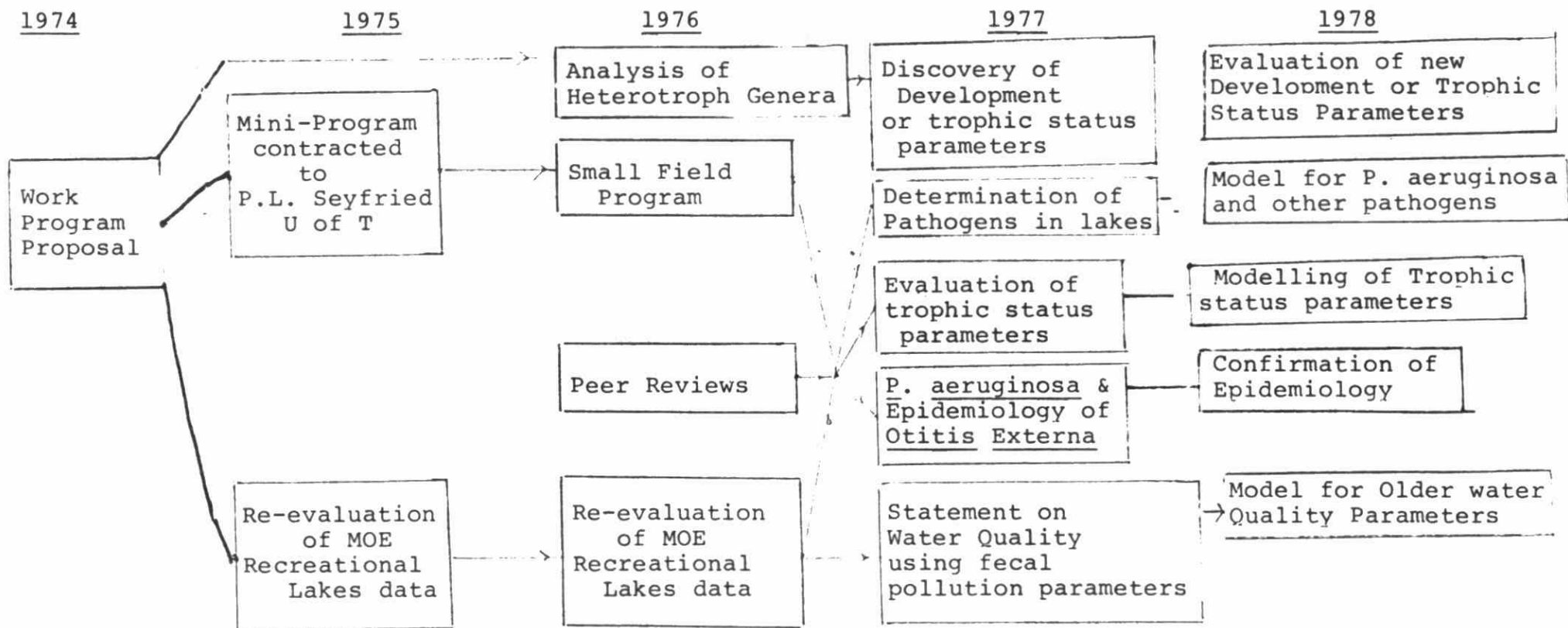
- 7 -
TABLE 2

Recreational Lakes and Lakeshore Capacity - Projects Initiated in 1977

PROJECT TITLE	Research Inventory		INTERIM REPORTS				FINAL
	No.		1977	1978	1979	1980	
The identification of fecal coliform bacteria isolated from the Sturgeon River near the Abitibi Paper Company	500-R01	GH - 7701					
Comparison of two media for the enumeration of fecal streptococci in water and the identification of streptococcal species at pollution sites in recreational lakes	500-R02	GH - 7702					
Determination of <u>Aeromonas hydrophila</u> in Recreational Lakes in Muskoka	511-R03	GH - 7703 KP					
Determination of <u>Acinetobacter</u> in Recreational Lakes in Muskoka	511-R04	GH - 7704 KP					
Epidemiology of otitis externa caused by <u>P. aeruginosa</u> among swimmers in Recreational Lakes	511-R06	GH - 7705 KP					
Determination of Bacteria in lake sediment by Elution followed by Membrane Filtration Technique	511-R07	GH - 7707 KP					
A sediment sampler suitable for the quantitative sampling of lake sediment	510-R09	GH - 7707					
The detection of Septic Tank leaks using labelled bacteria	510-R010	GH - 7708					

FIGURE - 1

FLOW CHART OF MICROBIOLOGICAL LAKESHORE CAPACITY STUDY

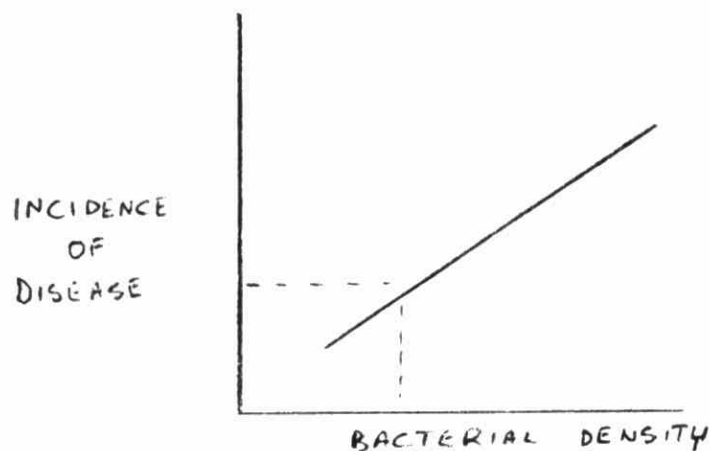


The Bacteriological Model

The model is in two parts. A multiple regression equation predicting water quality measured by the density of P. aeruginosa.

$$\begin{array}{rcll} \text{Density of} & = & \text{Trophic} & + \\ \text{P.A} & & \text{Status} & \text{Water} + \text{Development.} \\ & & & \text{Temp} \\ & & & \text{) lakes)} \end{array}$$

The measure of development would likely need to be weighted by the degree of people use. The second part of the model relates the amount of disease (otitis externa) to level of P. aeruginosa in the lake.



A level of disease in swimmers is related to a particular bacterial level in the lake water which is then equated to a quantity of development in the multiple linear regression model. Development could be limited by an unacceptable level of disease.

Interpretation of the 1977 Microbiology Results

1) Distribution of P. aeruginosa in eight lakes in Muskoka.

The lakes studied were:-

Harp

Jerry (Uncottaged)

Muskoka Bay

Fawn

Hurricane

Walker

3 - Mile

Gull Lake (Beach Only)

P. aeruginosa was determined in water and sediment samples taken at cottaged and uncottaged shoreline. For this study the definition of developed shore was simply lakeshore used for a human purpose - cottages, homes, and public beaches. Undeveloped shore was not used by humans in an obvious manner.

The mean density of P. aeruginosa in each sample was very low but higher densities were occasionally found along the developed shore particularly in lakes of higher trophic status or lakes experiencing intensive human use. Tables 3, and 4 show the frequency distribution of densities of P. aeruginosa in samples of water and sediment respectively in the eight lakes studied. The beach on Gull Lake, which experienced intensive swimming use, had the highest frequency of high levels of P. aeruginosa, whereas this bacterium was not isolated in the water and sediments of the undeveloped (Jerry) Lake.

The results of analysis of samples from the developed shoreline were compared to those taken along the undeveloped shore. There was a greater tendency for water samples taken at the developed shore to contain P. aeruginosa than those samples taken from the undeveloped sites (Table 5). This tendency was significant when the density of P. aeruginosa in the samples was considered. Each sample was weighted by a factor $X(\text{Density}/100 \text{ ml} + 1)$ (Table 6). This meant that greater numbers of water samples containing higher levels of P. aeruginosa

TABLE 3

FREQUENCY DISTRIBUTION OF DENSITIES OF
P. AERUGINOSA ISOLATED FROM SURFACE WATER.

BODY OF WATER	NUMBER OF SAMPLES AND RANGE OF DENSITIES OF P. AERUGINOSA DETECTED				
	>0-3	>3-10	>10-30	>30-100	>100-300
GULL LAKE BEACH	45	3	4	4	1
MUSKOKA BAY	5	1	1	1	
3-MILE L. E.	3				
3-MILE LAKE W.	7	1	1	1	1
WALKER	1				
FAWN	1				
HARP	3				
HURRICANE	1				
* JERRY					

* UNDEVELOPED LAKE

TABLE 4

FREQUENCY DISTRIBUTION OF DENSITIES OF
P. AERUGINOSA ISOLATED FROM LAKE SEDIMENTS.

BODY OF WATER	NUMBER OF SAMPLES AND RANGE OF DENSITIES OF P. AERUGINOSA DETECTED						
	1.8-3.0	>3.0-10	>10-30	>30-100	>100-300	>300-10 ³	>10 ³
GULL LAKE BEACH	9	5	2	2	1	1	
MUSKOKA BAY		5					
3-MILE LAKE E.	3	1					
3-MILE LAKE W.	2						
WALKER	2		1				
FAWN		2					
HARP			1				
HURRICANE							
* JERRY							

* UNDEVELOPED LAKE.

TABLE 5

INCIDENCE OF P. AERUGINOSA (PA) IN SHORELINE
SURFACE WATER SAMPLES IN SUMMER.

TYPE OF SHORELINE	NUMBER OF PA +VE SAMPLES	NUMBER OF PA NIL SAMPLES	TOTALS	FREQUENCY % +VE
DEVELOPED	14	179	193	7.25
UN-DEVELOPED	5	112	117	4.27
TOTALS	19	291	310	6.12

$$X^2 = 1.13 \quad P = 0.289$$

TABLE 6.

INCIDENCE OF P. AERUGINOSA, WEIGHTED* FOR
SAMPLE DENSITY, IN SUMMER SHORELINE
WATER SAMPLES.

TYPE OF SHORELINE	SUM OF PA DENSITIES	WEIGHTED NUMBER OF PA +ve SAMPLES	WEIGHTED NUMBER OF PA NIL SAMPLES	MEAN PA PER SAMPLE
DEVELOPED	228	242	179	1.18
UN-DEVELOPED	7	12	112	0.06
TOTALS	235	254	291	0.76

* EACH SAMPLE WAS WEIGHTED $\times (\text{DENSITY}/100n! + 1)$

$$\chi^2 = 87.91 \quad P = 0.000.$$

were found along the developed shore.

A significantly greater number of sediment samples containing P. aeruginosa were found at the developed rather than the undeveloped shoreline. (Table 7). A higher level of significance was obtained when the density of P. aeruginosa in the samples was accounted for by multiplying each sample by (Density/100 ml + 1). (Table 8).

Levels of P. aeruginosa in water samples were a higher than those found in the sediment samples (Tables 6 and 8). This was contrary to our expectation and it was concluded that the method of determination of P. aeruginosa in sediments was not sensitive as it should be. Improvements are being worked out now and should be available by spring 1978.

More information was obtained when the developed sites were divided into different types. A comparison was made of the percentage of samples containing P. aeruginosa from different types of shoreline in Table 9 and 10. The major contribution of P. aeruginosa was from Public beaches and cottaged areas. The contribution from public beaches was particularly high. In conclusion it was shown that P. aeruginosa densities related to the development and trophic status of lakes and therefore two components of the model were correctly identified.

The third component of the model is surface water temperature, and this summer was observed to be about 22°C. The summer range was 16°C to 25°C. This was expected to be a little below the level of temperature at which P. aeruginosa

TABLE 7.

INCIDENCE OF P. AERUGINOSA (PA) IN SHORELINE

SEDIMENT SAMPLES IN SUMMER.

TYPE OF SHORELINE	NUMBER OF PA +VE SAMPLES	NUMBER OF PA NIL SAMPLES	TOTALS	FREQUENCY % +VE
DEVELOPED	14	216	230	6.09
UN- DEVELOPED	2	143	145	1.38
TOTALS	16	359	375	4.27

$$\chi^2 = 4.83 \quad p = 0.028.$$

TABLE 8.

INCIDENCE OF *P. AERUGINOSA*, WEIGHTED* FOR

SAMPLE DENSITY, IN SUMMER SHORELINE SEDIMENTS.

TYPE OF SHORELINE	SUM OF PA DENSITIES	WEIGHTED NUMBER PA +ve SAMPLES	WEIGHTED NUMBER PA NIL SAMPLES	MEAN PA PER SAMPLE
DEVELOPED	59.2	73.2	216	0.26
UN-DEVELOPED	14.5	16.5	143	0.10
TOTALS	73.7	89.7	359	0.20

* EACH SAMPLE WAS WEIGHTED $\times (\text{DENSITY}/100m^2 + 1)$

$$\chi^2 = 14.40 \quad P = 0.0001.$$

TABLE 9.

FREQUENCY OF ISOLATION OF P. AERUGINOSA (PA) IN
SAMPLES OF WATER TAKEN AT DIFFERENT TYPES
OF DEVELOPED AND UNDEVELOPED SHORELINE

TYPE OF SHORELINE	PA +ve SAMPLES	PA NIL SAMPLES	FREQUENCY % +ve
COTTAGED	10	128	7.24
PUBLIC BEACHES	59	87	40.41
COMMERCIAL	2	26	7.14
UNDEVELOPED	5	121	3.96

TABLE 10.

FREQUENCY OF ISOLATION OF P. AERUGINOSA (PA) IN
SAMPLES OF SEDIMENTS TAKEN AT DIFFERENT TYPES
OF DEVELOPED AND UNDEVELOPED SHORELINE.

TYPE OF SHORELINE	PA +ve SAMPLES	PA NIL SAMPLES	FREQUENCY % +ve
COTTAGED	8	159	4.79
PUBLIC BEACHES	21	36	26.93
COMMERCIAL	3	31	8.82
DEVELOPED FARM	2	10	16.67
UNDEVELOPED	2	143	1.37

would grow well in the lake. This years results support this conclusion since the levels of P. aeruginosa were low. Older recreational lake reports record surface water temperatures between 19° C and 25°C. Other years may give higher water temperatures and so higher levels of P. aeruginosa in the water, but recently temperature seems not to have played a large part in promoting the growth of P. aeruginosa in recreational lakes. It remains an important consideration.

Evidence From Previous Recreational Lakes Studies

ASSOCIATION OF BACTERIAL POLLUTION WITH DEVELOPED SHORELINE IN RECREATIONAL LAKES

Shoreline pollution was considered to be of a diffuse type and was difficult to trace to a point source. Consistently high levels of bacteria were noted at shoreline locations but they were rarely linked to a shoreline source. The shoreline pollution appeared to have been spread out from its source and was termed a nonpoint source.

In order to test the association of this kind of pollution with shoreline development, the data was ordered in the following way. For this test cottages, public bathing beaches, lodges, camps, marinas, public parks or other obvious examples of lakeshore development were found on the developed shore. Undeveloped shoreline was considered free of such structures and activities. Minor signs of development, i.e. those not involving immediate human use, like road clearance, telephone poles and culverts were ignored for this test. The sampling stations at inflows, the outfall, and midlake stations were set aside as they

were considered not to be of value when examining shoreline contributions of bacteria. The remaining stations were put into two groups, one consisting of those monitoring the developed sections of lakeshore, and the other consisting of those monitoring the undeveloped sections of shoreline. Pollution was measured by the frequency of pollution events at a sampling location, where a positive pollution event was one where the FC geometric mean density at a location along the shore was significantly higher, determined by an analysis of variance, than that of the main body of water surrounding that shoreline location. A pollution negative event was one where the FC geometric mean density was lower than the main body of water about that location. This appeared to indicate an inflow of water cleaner than that of the surrounding lake. The FC geometric mean densities at many shoreline locations were the same as the surrounding lake and they were recorded as pollution nil.

The numbers of sampling stations with the three types of pollution events at developed and undeveloped shore in each season of the year are displayed in Table 11. These data may be simply tested by an analysis of frequency. There were some significant seasonal differences and a difference associated with shoreline development.

The comparison between summer pollution events at the developed and undeveloped shore was absolute, 14 on the developed shore, and 0 on the undeveloped shore. The overall comparison with significant χ^2 test is shown in table 12. It was concluded that in summer, when recreational activity is highest, fecal pollution is highest, in fact is only found, on the developed shore where cottages and septic tanks were found.

TABLE 11

Comparison of Seasonal Variation in Frequency of FC Pollution Events at Developed and Undeveloped Shore

	Season of Lake Survey	Numbers of Stns, at which Pollution can be Registered				Frequency % + ve	Frequency % - ve	Range of GM Values Pollution + ve FC/100 ml	χ^2
		Pollution + ve	Pollution Nil	Pollution - ve	Totals				
Developed Shore	Spring	5	218	0	223	2.24	0	4.6 - 17.0	
	Summer	14	266	4	284	4.76	1.41	3.2 - 18.5	
	Fall	2	82	0	84	2.38	0	4.6 - 6.3	
	Total	21	566	4	591	3.55	0.68	4.6 - 18.5	7.5
Undeveloped Shore	Spring	2	168	0	170	1.18	0	3.0 - 7.0	
	Summer	0	197	1	198	0	0.51	-0	
	Fall	1	66	0	67	1.49	0	3.3	
	Total	3	431	1	435	0.69	0.22	-	3.8
Total Shore	Spring	7	386	0	393	1.78	0	3.0 - 17.0	
	Summer	14	463	5	482	2.90	1.04	3.2 - 18.5	
	Fall	3	148	0	151	1.99	0	3.3 - 6.3	
	Total	24	997	5	1026	2.33	0.48	-	7.0

TABLE 12.

ASSOCIATION of FECAL POLLUTION (FC)
WITH DEVELOPED SHORELINE.

TYPE OF SHORELINE	FC POLLUTION +ve	FC POLLUTION NIL	TOTAL	FREQ % +ve
DEVELOPED	21	566	587	3.57
UN DEVELOPED	3	431	434	0.69
TOTALS	24	997	1021	2.35

$$\chi^2 = 9.056$$

$$p = 0.003$$

The results are not as clear when the numbers of fecal streptococcus are used but the overall comparison gave a significant association of fecal streptococcus pollution with the developed shoreline (not illustrated). It should be noted that the levels of fecal pollution were well below the recreational criteria (Table 11).

Low levels of fecal pollution and pollution by P.aeruginosa have been demonstrated to be associated with cottaged shoreline in recreational lakes. It was concluded that the effect of single tier cottage development on lake water quality was detectable but low enough not to be a large public health nuisance.

Future Studies

Single tier cottage density is the low end of the scale of development. Its effects can be detected but to demonstrate a scale of effects it is necessary to look at examples of more dense development. The examples that we are looking for will concentrate more people (swimmers) on the shoreline than are found with single tier cottage development. The type of development that we can study are:-

1. Clustered cottage developments
2. Lodges
3. Camps
4. Trailer Parks
5. Public Parks
6. Public Beaches

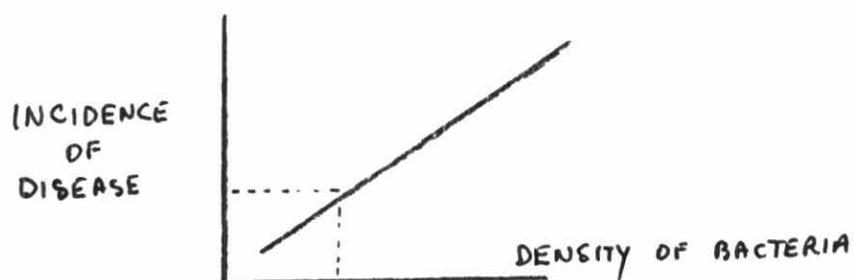
The bacteriological model does not change but the method of application depends now on Lakeshore use. It is Lakeshore site specific.

Bacterial densities are predicted at a given site by a multiple regression equation as before with small modifications.

$$P. aeruginosa = \text{Trophic Status} + \text{Water Temp} + \text{Development}$$

Trophic status may be for the lake as a whole or a measurement of heterotrophic bacteria at that specific site. Development is measured as number of swimmers / 100 ft. of Lakeshore (at that site).

The means of controlling the numbers of people using the shore is still the incidence of disease:



The means of controlling the size of the backlot style of development is through the density of swimmers/unit of available lakeshore that the development produces. Different kinds of development can be treated in the same manner since the unit of development would remain the same.



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